OPTIMIZING DATA COLLECTION, DATA AVAILABILITY, AND STREAMFLOW FORECASTING TO ENHANCE FISHERIES IN THE SNAKE RIVER WATERSHED

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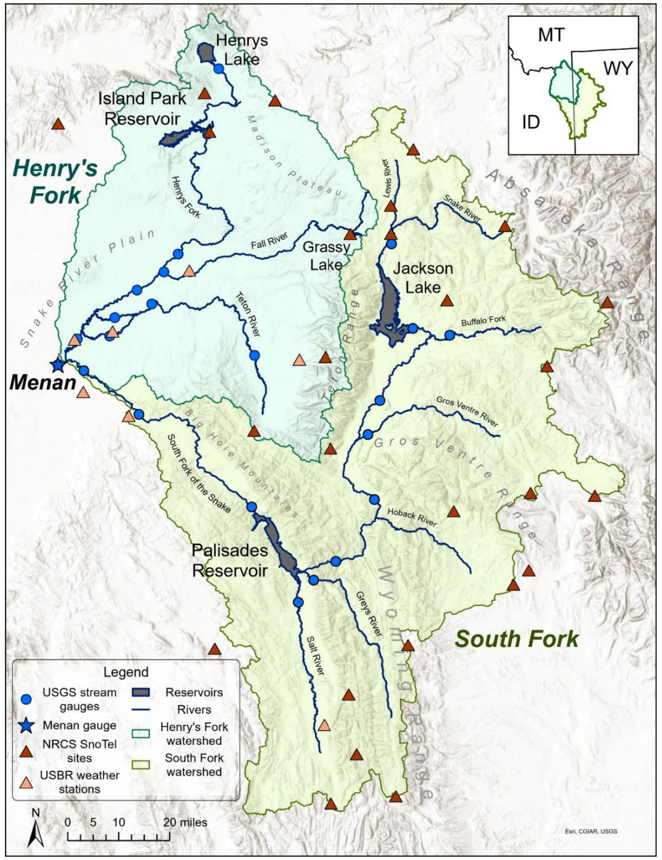
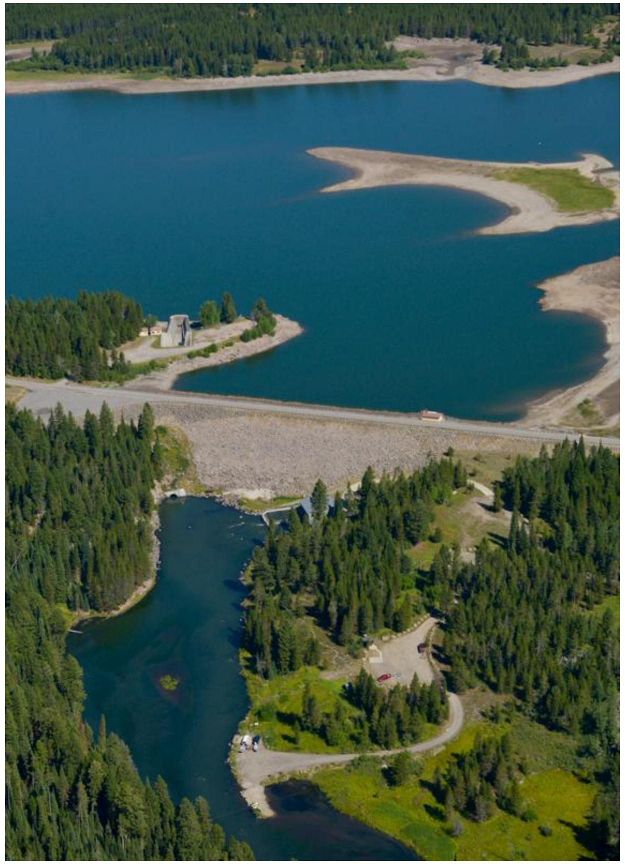




PROJECT OVERVIEW

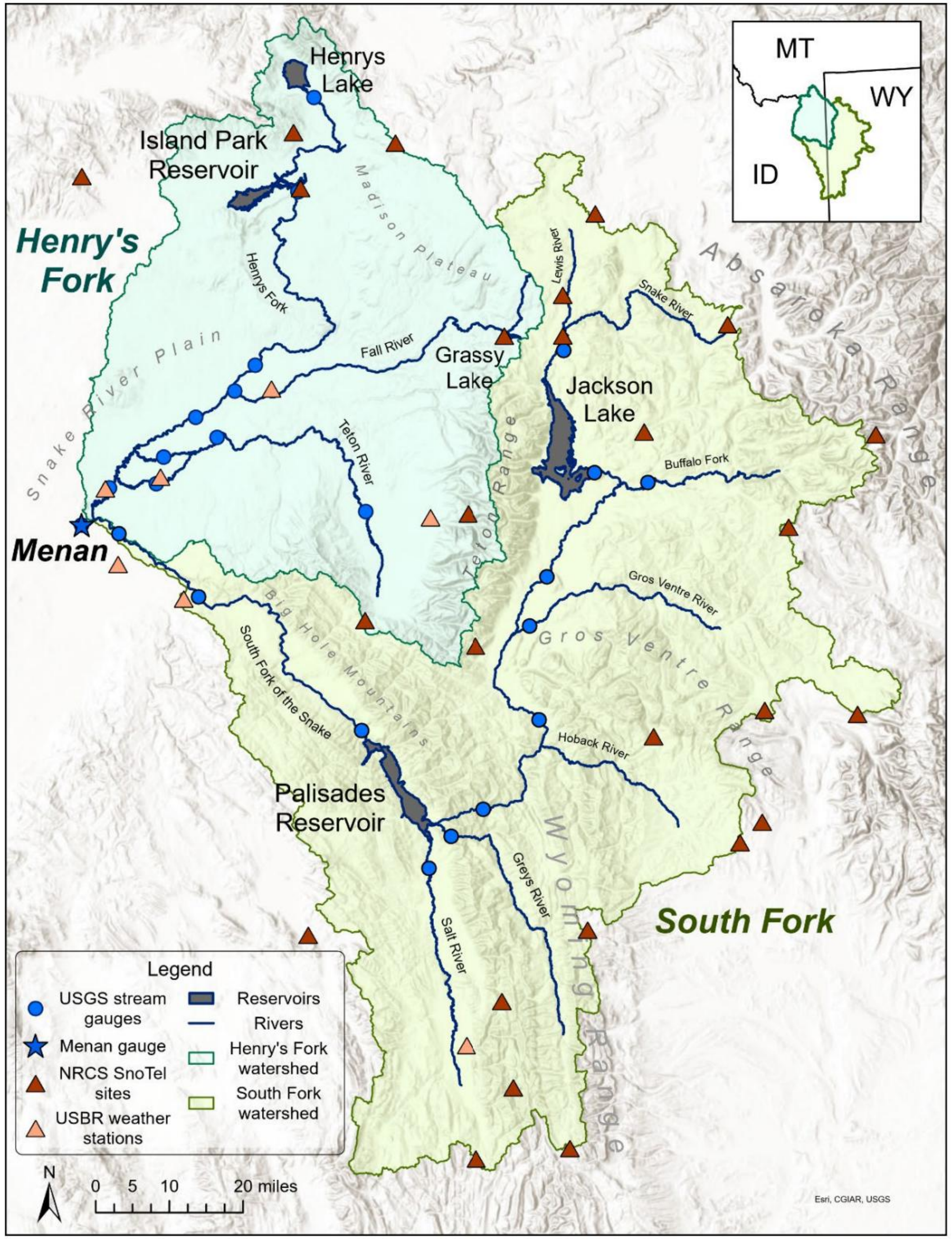
Provide new data to inform management of reclamation facilities in the upper Snake River basin (USRB)

1) **Expand existing hydrologic monitoring** in the Henrys Fork to the entire upper Snake river system

2) **Develop new methods to predict seasonal natural water supply** over the watershed

PROJECT LOCATION

- Upper Snake River basin (**USRB**)
  - Snake River watershed upstream of Menan, ID
  - Includes Henrys Fork, South Fork, and Snake Headwaters sub-watersheds
- Storage reservoirs include: Island Park Reservoir, Henrys Lake, Grassy Lake, Palisades Reservoir, Jackson Lake



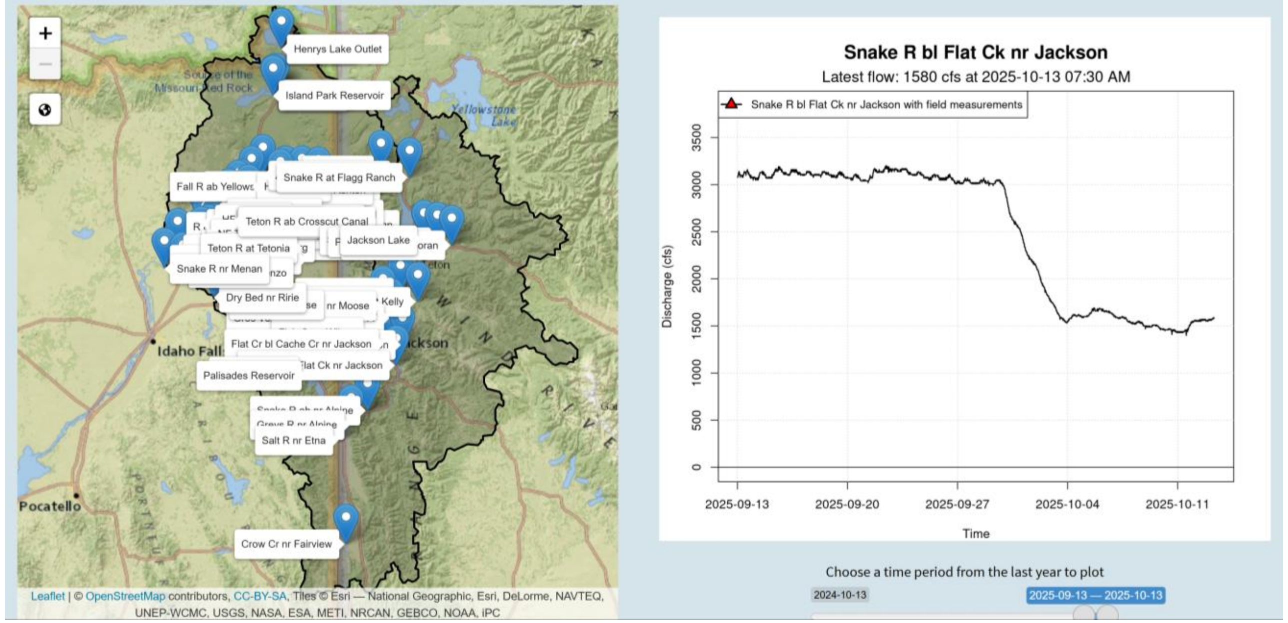
PROJECT GOALS

1) Provide **continuously updated daily-scale and real-time hydrologic data** to support science and management throughout the upper Snake watershed.
2) Develop subwatershed-scale seasonal **predictive models of (unregulated) water supply** and reservoir operations in this watershed.
3) Support development of the next generation of physically based short-term snowmelt runoff models to **improve reservoir operations during the spring and early summer**.

In simpler terms: Improve our knowledge of out how much water is in the watershed, when that water turns to streamflow, and when it is needed by downstream users

EXPANDING EXISTING HYDROLOGIC MONITORING

- Compile existing climate, regulated streamflow, and reservoir storage data
  - Using long-term weather, stream gaging, reservoir level, and irrigation diversion stations in the USRB
- Develop a predictive model of water-rights priority based on publicly available data
- Predict surface-water irrigation demand for the SRH ahead of the irrigation season.
- Christina Morrisett & Rob Van Kirk are leading this effort



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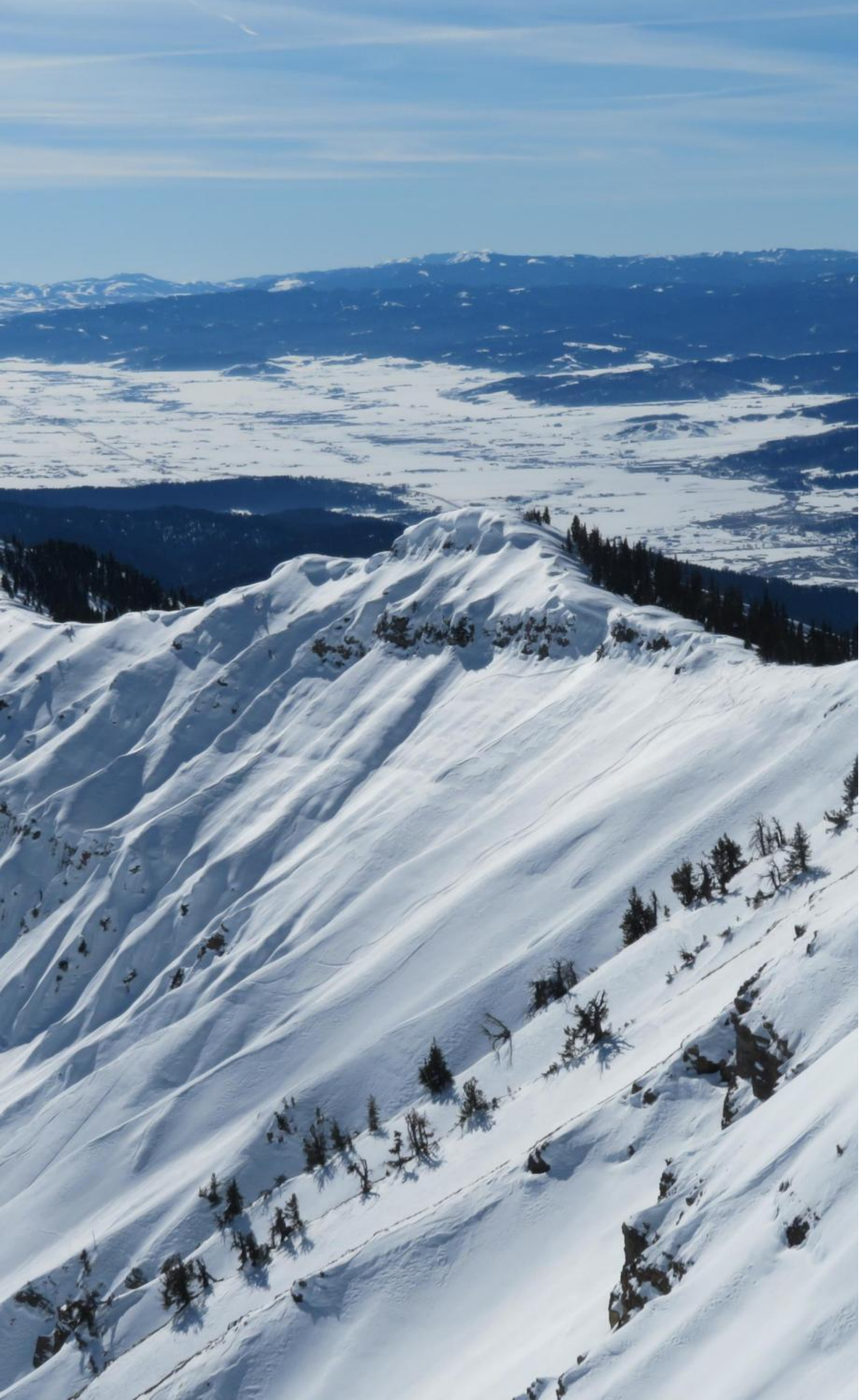


PREDICTING SEASON UNREGULATED WATER SUPPLY: SEASONAL SNOWPACK

- >70% of all precipitation in the upper Snake watershed falls as snow during the cool season
- Water accumulates as **seasonal snowpack** in fall-winter an **melts in spring-summer**
- This accumulated **Snow Water Equivalent (SWE) is the region's main natural water supply**

- Ideally, we would know:
  - How much SWE
  - When it will melt
  - How much ends up as streamflow

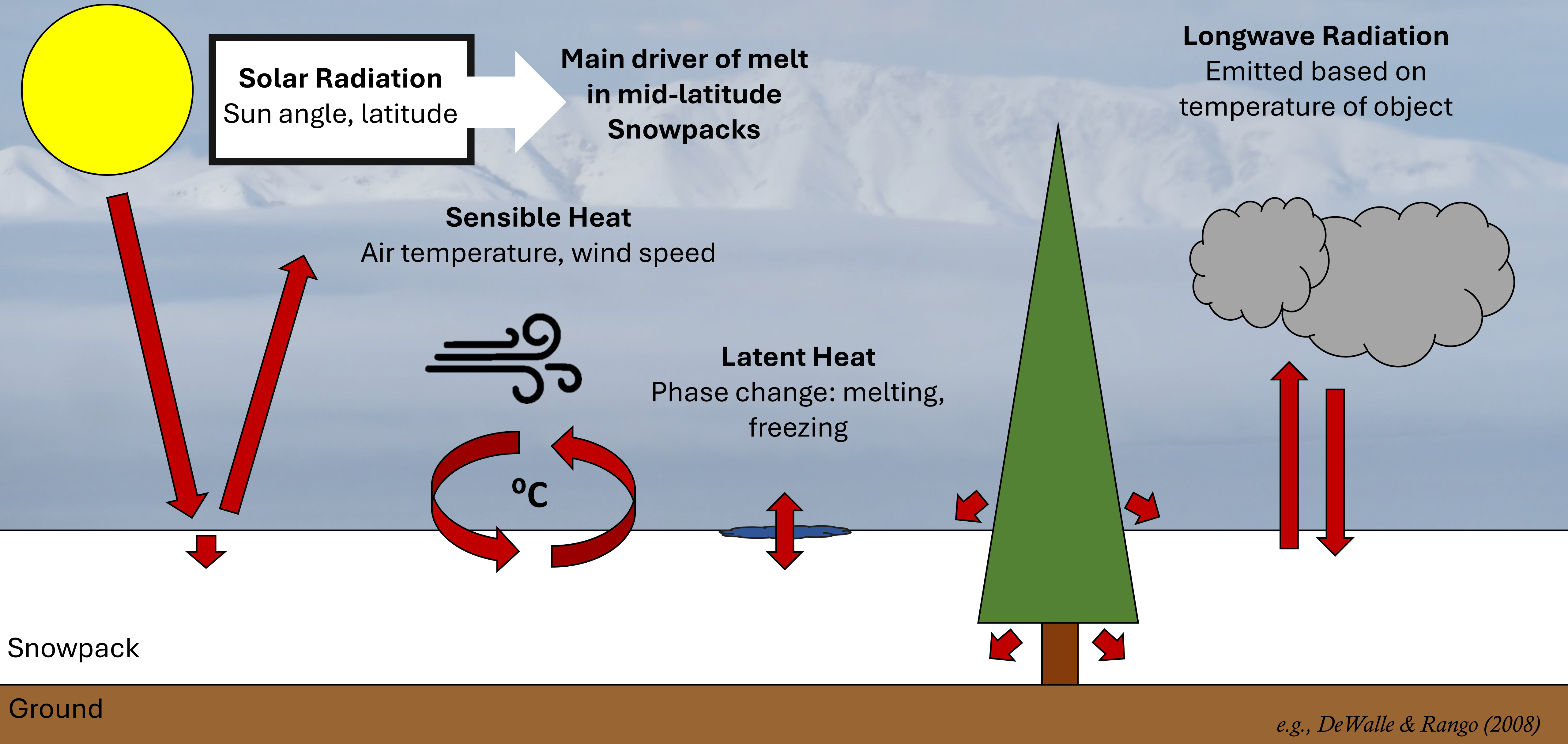
e.g., Li et al. (2017); Van Kirk (2020)

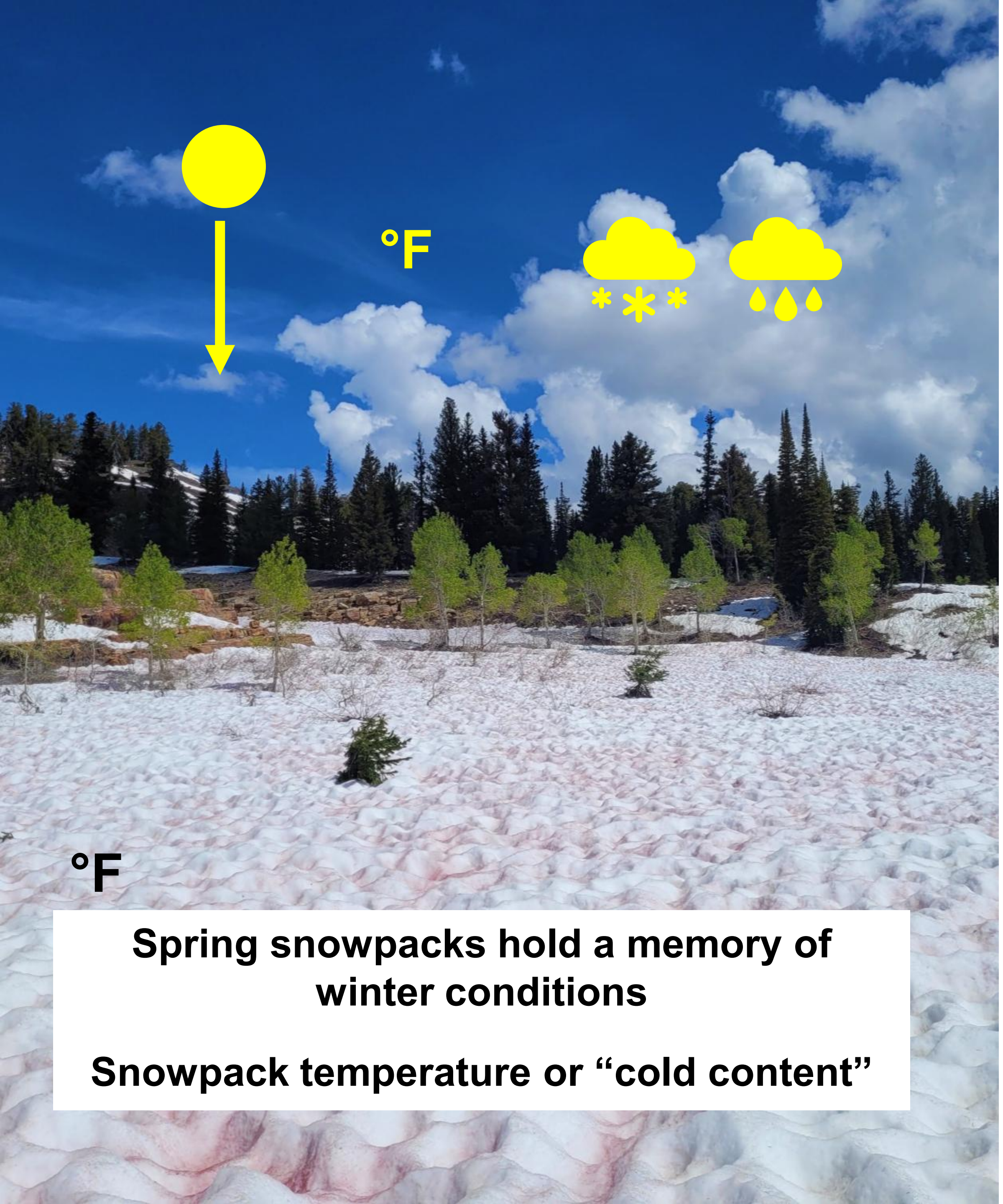
PREDICTING WATER SUPPLY DURING SNOWMELT

- Accurately predicting snowmelt timing and magnitude is difficult, and a large source of uncertainty in water supply forecasting
- Why is it so hard to get this right?

HOW DOES SNOW MELT?

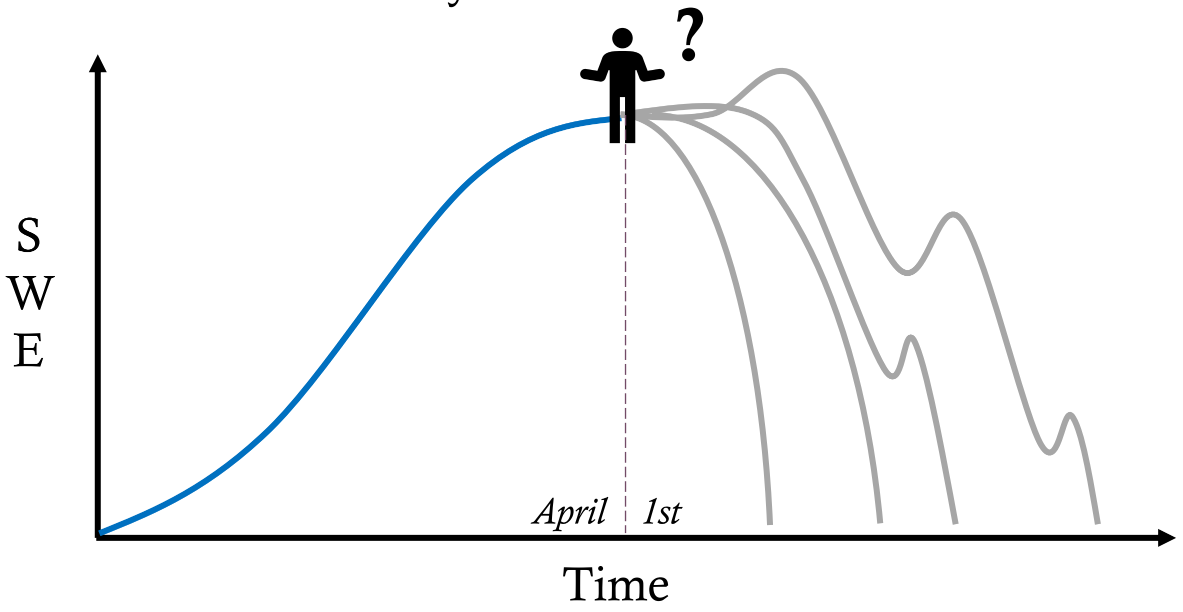
Weather has the main impact





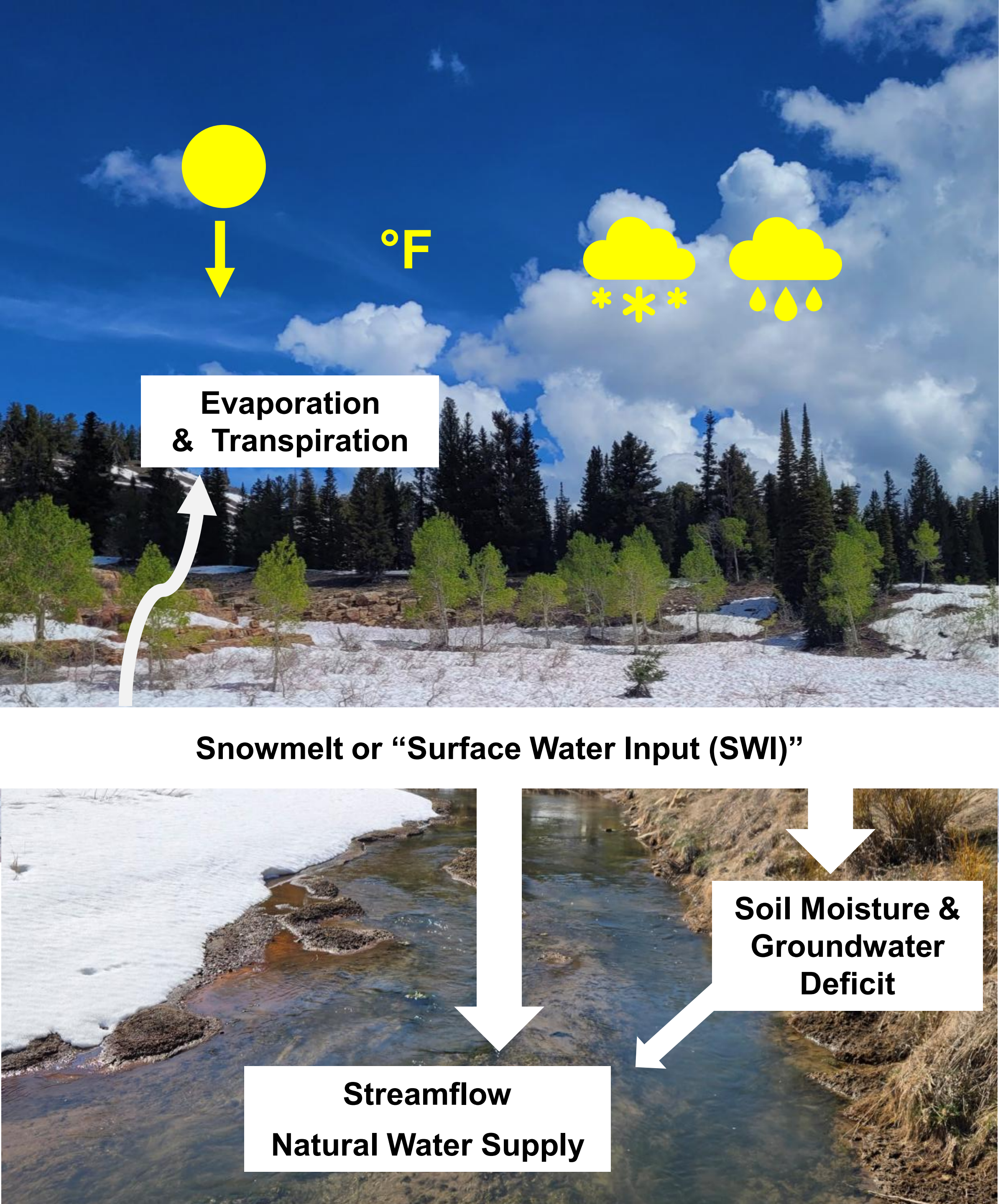
PREDICTING WATER SUPPLY DURING SNOWMELT

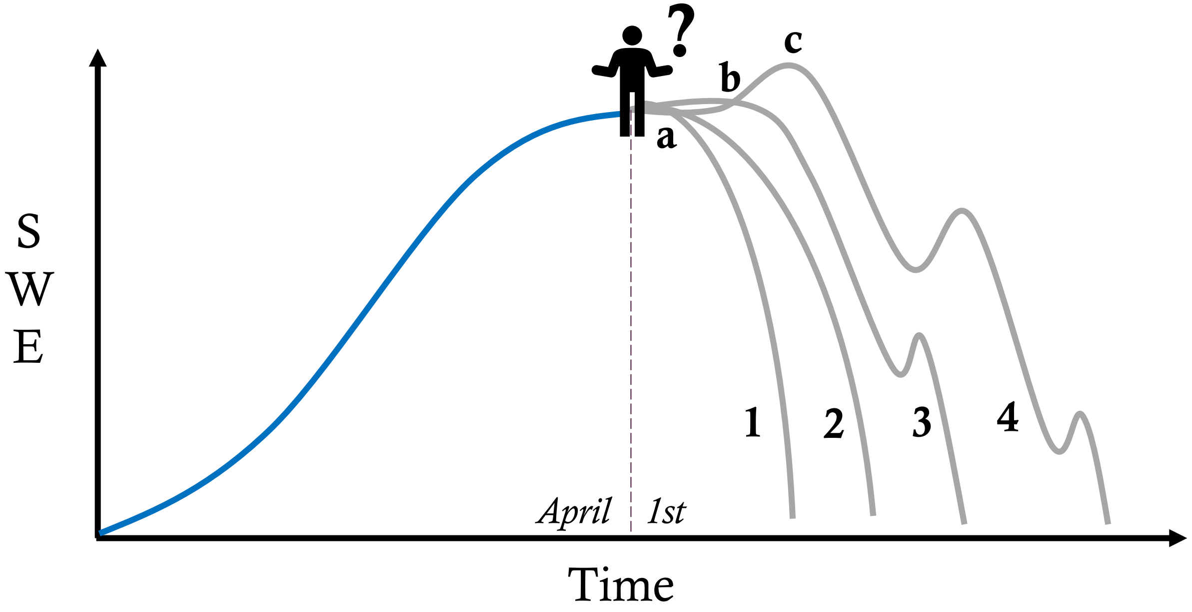
- **Why is it so hard to get this right?**
  - Weather is hard to predict, and impact of weather on snowmelt varies by season



- Even in two years with identical spring conditions, snowmelt can behave differently based on winter history

PREDICTING WATER SUPPLY DURING SNOWMELT



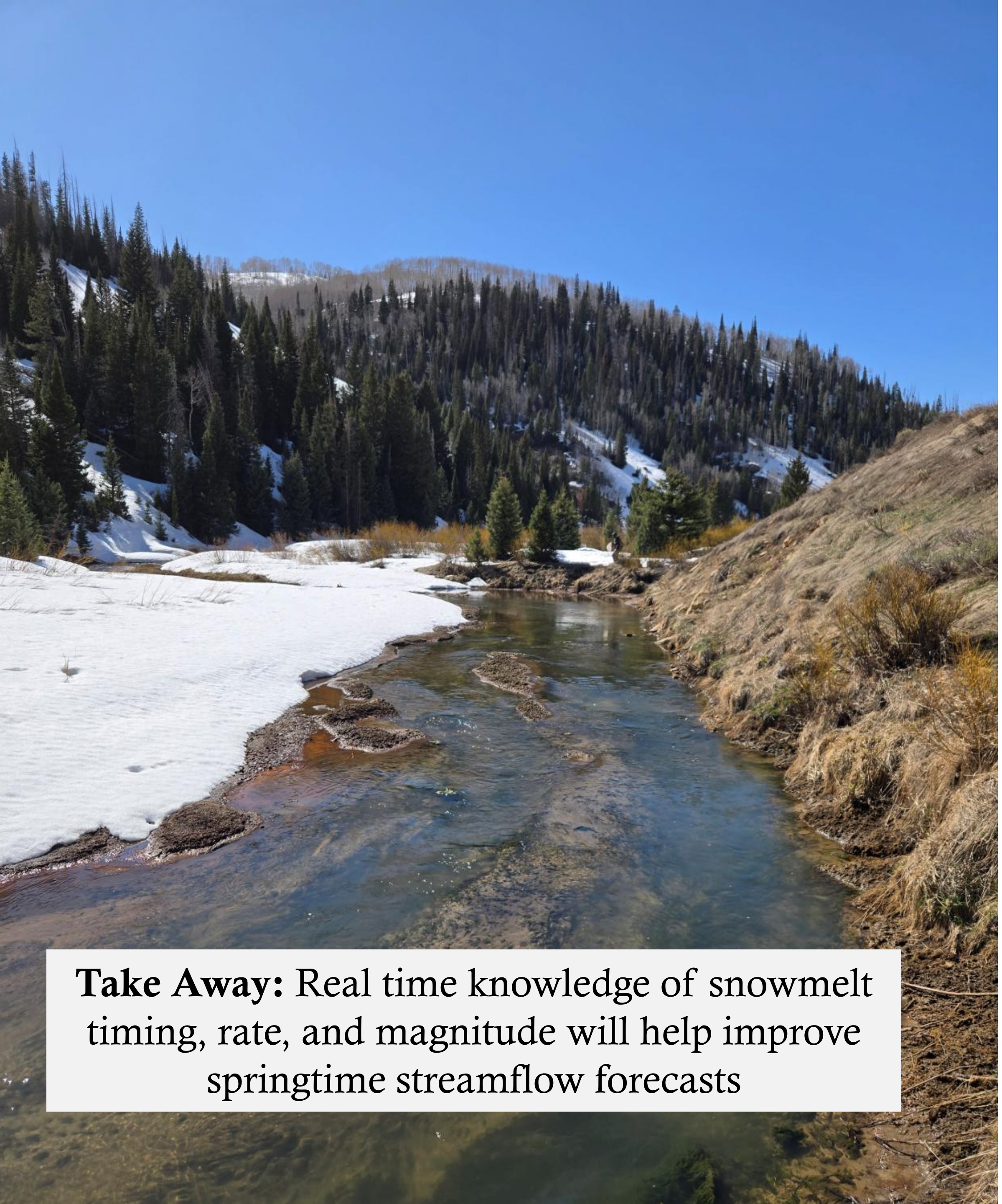


- Timing of snowmelt onset (**a, b, c**) and different snowmelt rates (**1, 2, 3, 4**) can result in different runoff efficiencies and operational practices

- Snowmelt character can determine streamflow response

- No two seasons are exactly alike!

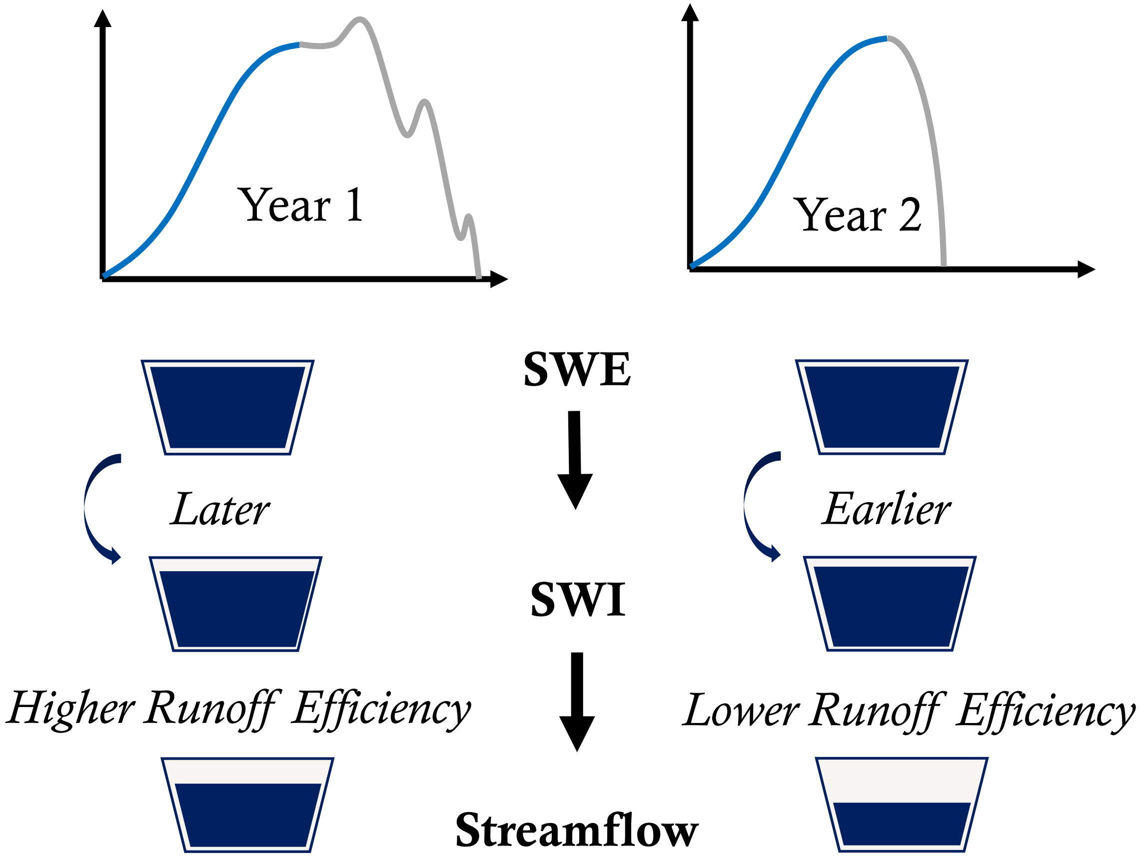
e.g., Hale et al. (2023)



Take Away: Real time knowledge of snowmelt timing, rate, and magnitude will help improve springtime streamflow forecasts

PREDICTING WATER SUPPLY DURING SNOWMELT

Example scenario (not always true)

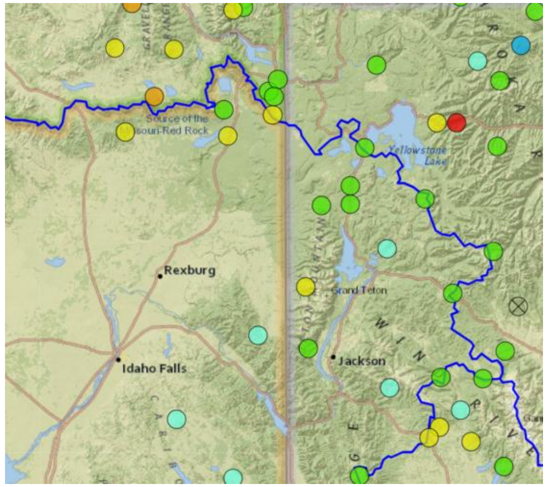


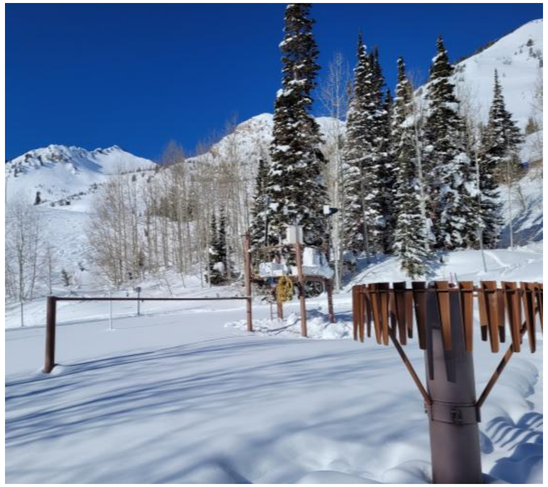
Snowmelt-to-streamflow response can vary seasonally <u>and regionally</u>

e.g., Newcomb et al. (2024)

PREDICTING WATER SUPPLY DURING SNOWMELT

- What tools do we have currently?
  - **SNOTEL Sites**
    - Real time SWE & snow depth at specific points in a watershed
    - Designed to establish calibrated relationships with streamflow
    - Very informative, widespread
    - Have limitations
      - Generally don't represent highest elevations
      - Similar terrain between sites
      - Limited sensors

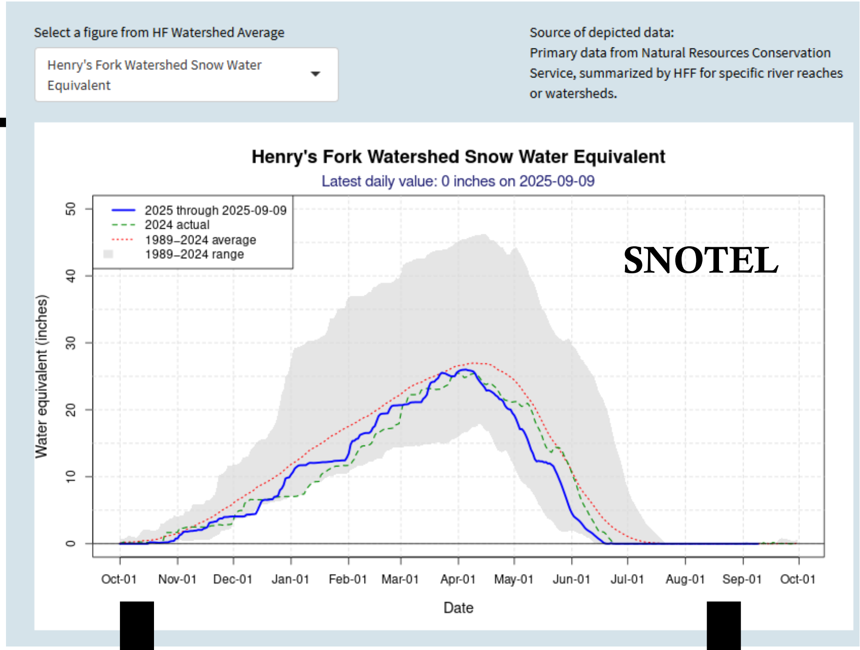


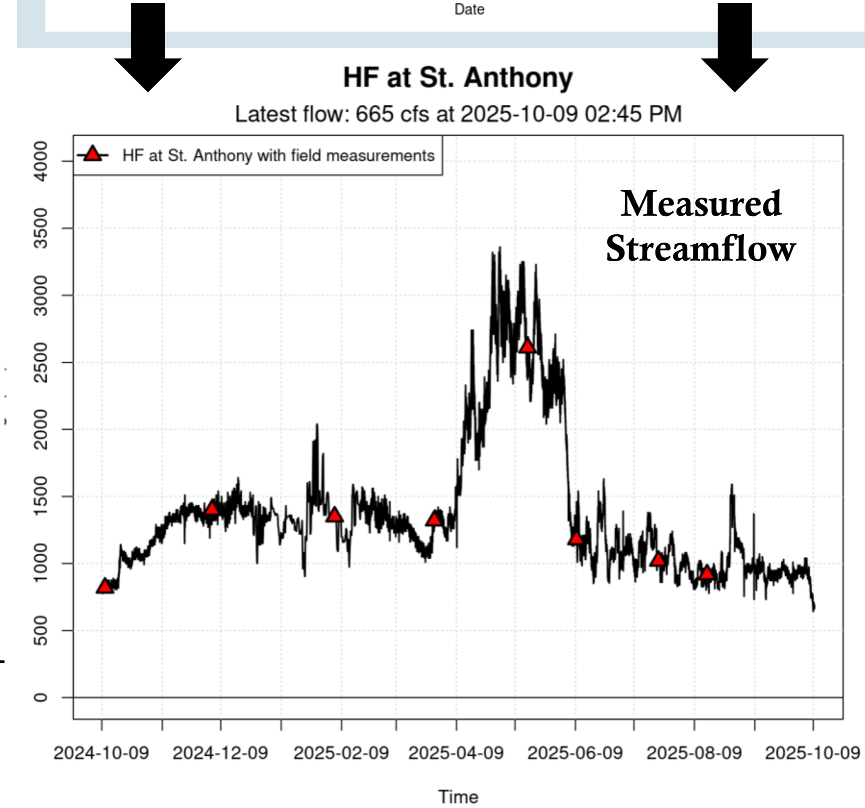


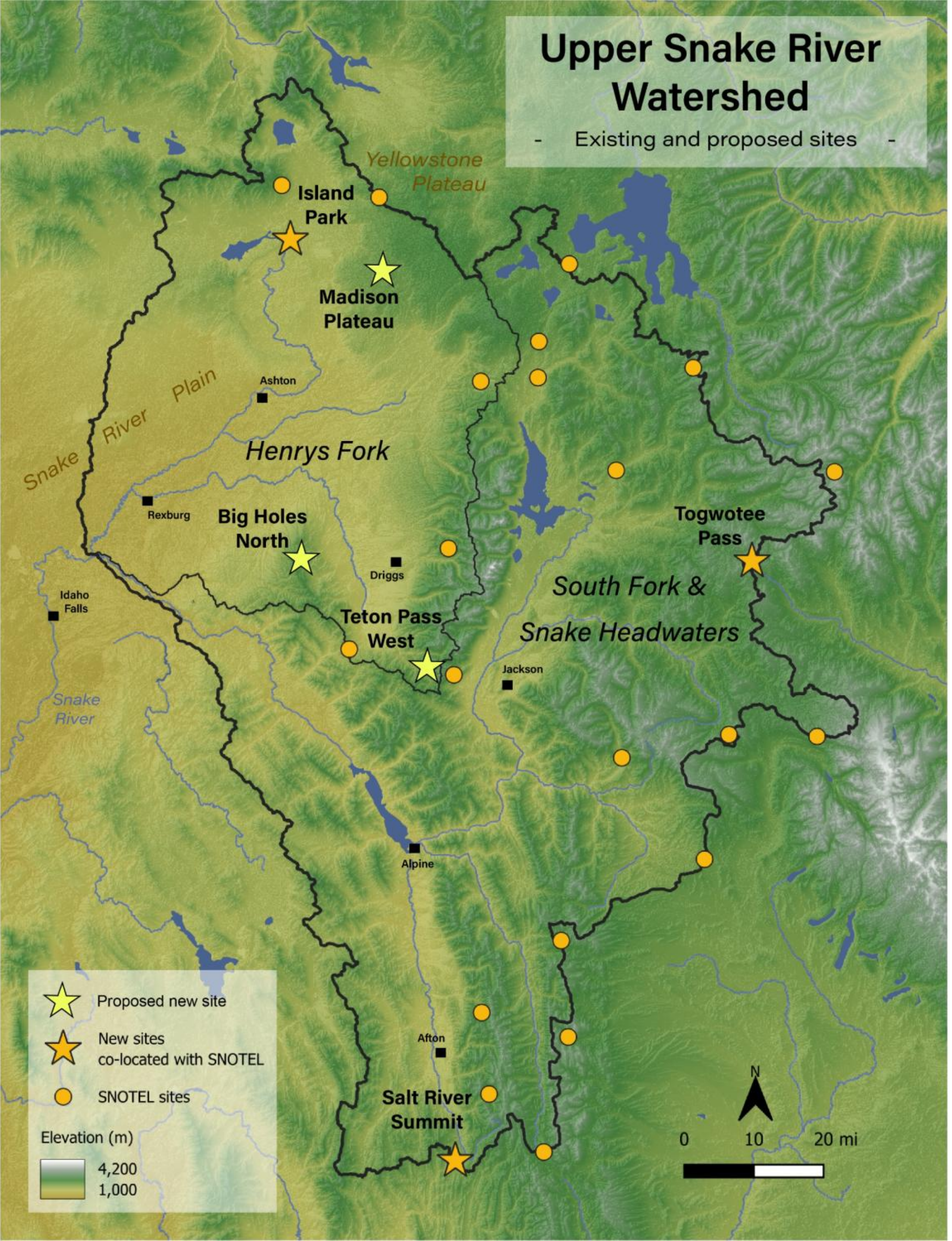
NRCS

PREDICTING WATER SUPPLY DURING SNOWMELT

- What tools do we have currently?
  - **Statistical relationships between SNOTEL and streamflow**
    - Very useful if there is a long historical record
    - Highly effective, simple, accurate under many conditions
  - Also has limitations
    - Performance declines when there are unrepresented conditions, outside of historical norms
    - Relies on long records
    - Non-physical (i.e., not directly simulating what controls melt)







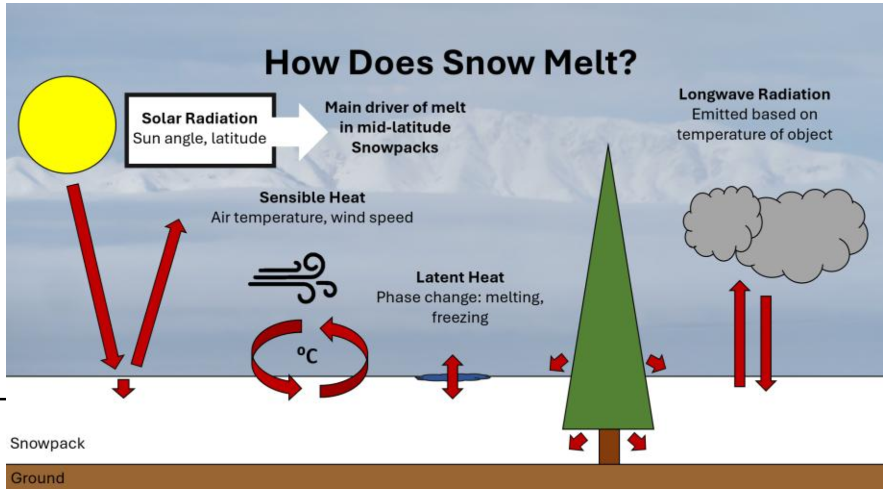
WHAT WE'LL DO

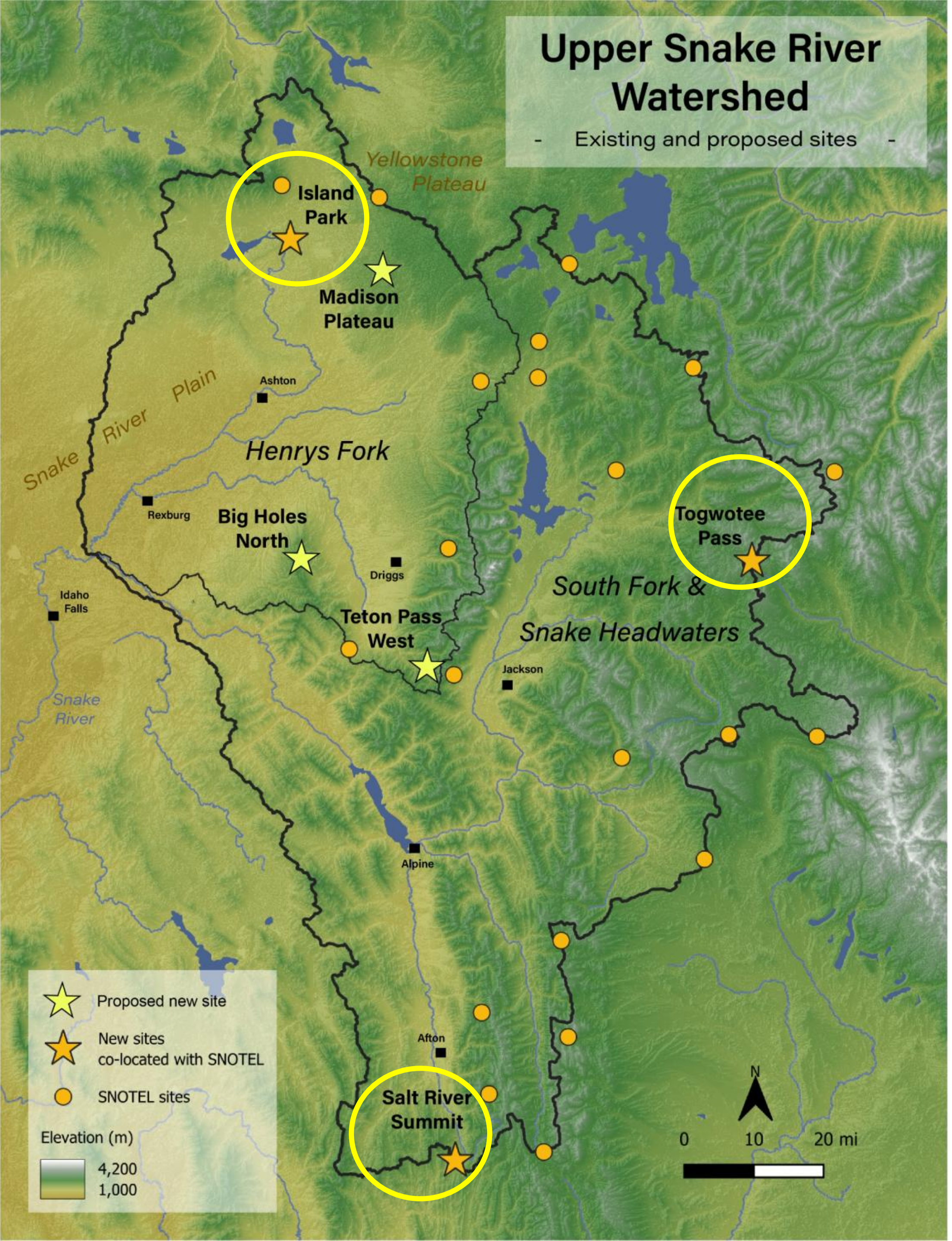
- **Step 1: Expand monitoring network** by installing 6 new sites
- Integrate data collected from these sites into existing operations practices
- 3 near existing SNOTEL locations:
  - Island Park
  - Togwotee Pass
  - Salt River Summit
- 3 sites in new locations
  - Western end of the Madison Plateau
  - Northern Big Hole Mountains
  - Western side of Teton Pass

Example of a similar station
Image: William Roe (UofU)

WHAT WILL THESE SITES LOOK LIKE?

- Movable, semi-permanent towers
- Remote transmission of data via cellular network
  - Minimal maintenance
- Each station will be configured to optimize information recorded at a given location
- Focus will be on **measuring variables that control snowmelt**
  - Solar radiation (incoming sunlight)
  - Longwave radiation (thermal energy emitted by clouds, trees, ground)
  - Temperature, humidity
  - Wind speed, direction
  - Precipitation





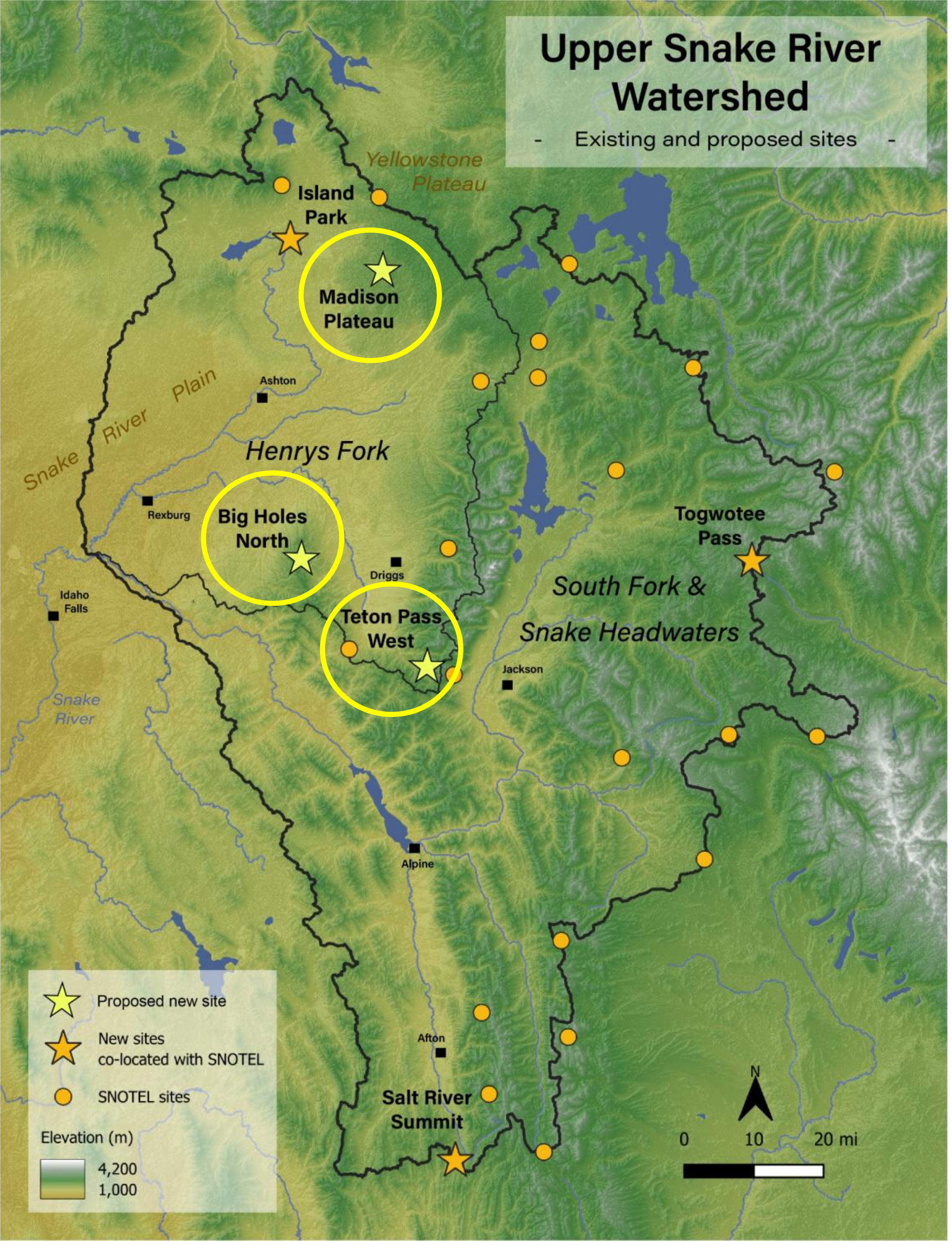
CO-LOCATED SITES

- 3 near existing SNOTEL locations:
  - Island Park
  - Togwotee Pass (within 1 mile)
  - Salt River Summit

- Supplement existing records
- Provide new monitoring variables (wind speed, humidity, 4-component radiation, etc.)
- Mostly high-elevation, snow-dominated regions, accessible
- Placement in adjacent land cover types
  - Forested/meadow, unburned/burned

SELECTED CO-LOCATED SITE

Station will be directly adjacent to SNOTEL, but provide supplementary measurements in burned canopy



NEW SITES

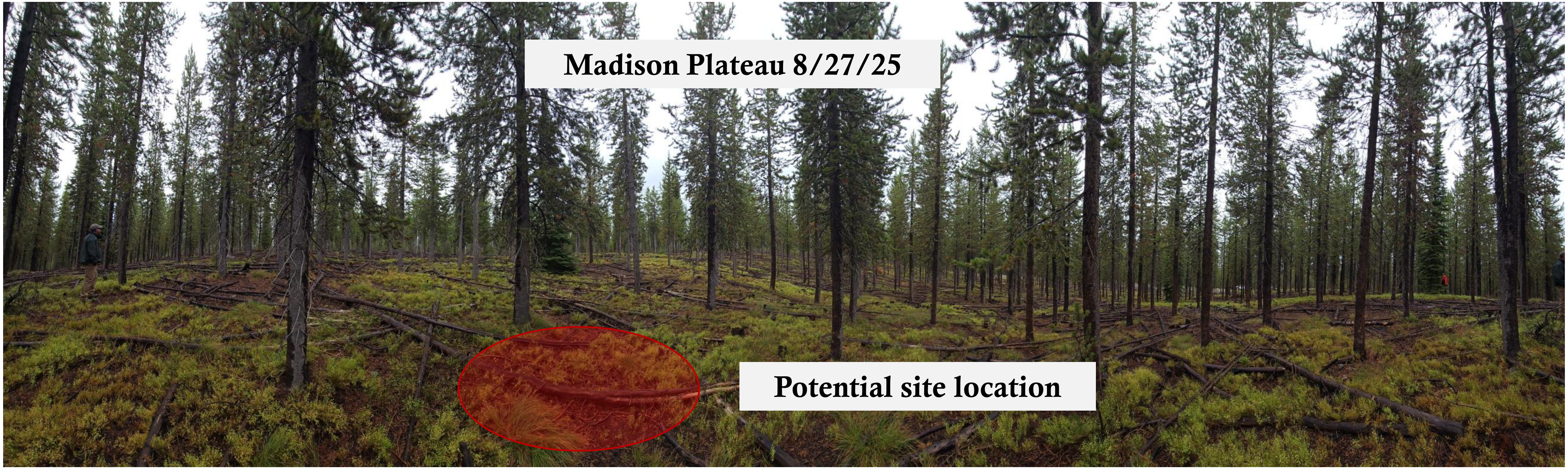
- Spatially underrepresented terrain
  - High elevations
  - Unconventional locations for snow-study sites
- Hydrologically significant
- Relatively accessible year-round

1) Forested site on Madison plateau
2) Near-ridgeline site at northern end of Big Hole Mountains
3) Open South-facing meadow on western side of Teton Pass

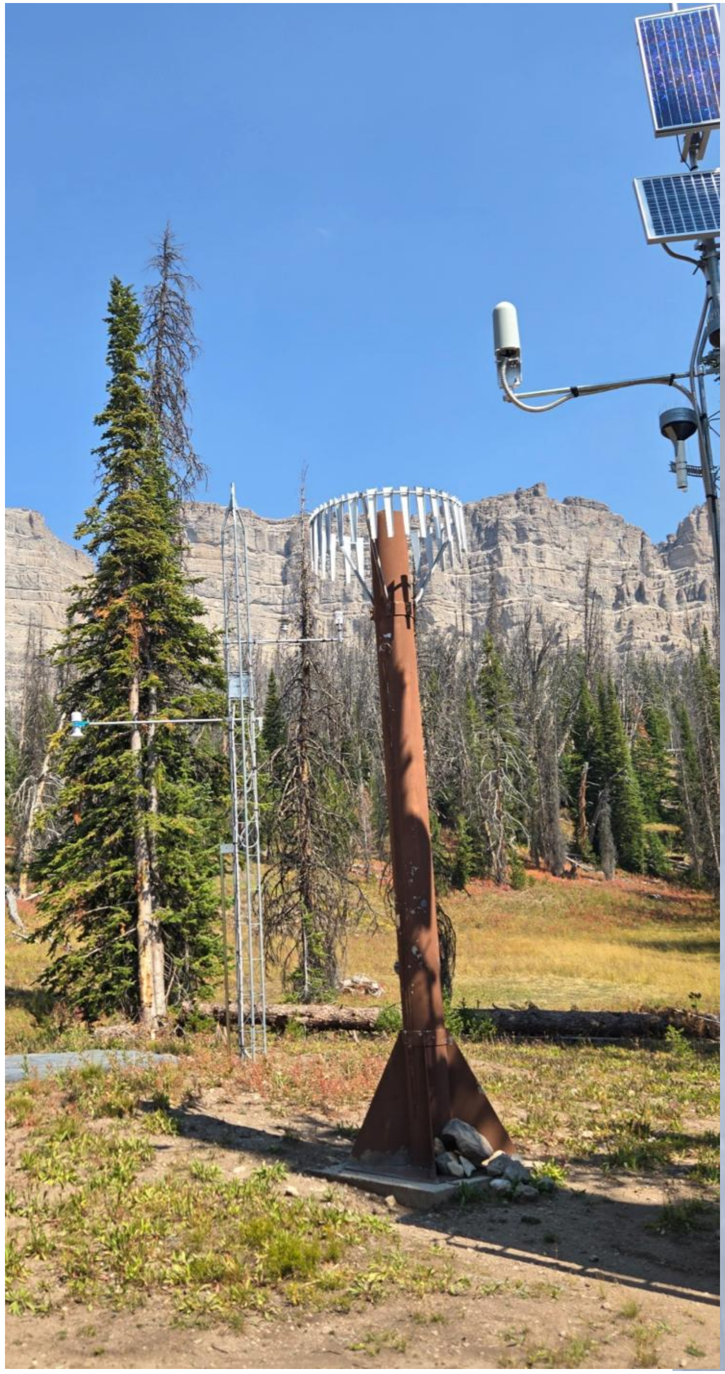
SELECTED "NEW" SITE

Station will be far from any SNOTEL site, but still near existing meteorological instrumentation

SELECTED NEW SITE



Station far from any existing meteorological instrumentation, will provide insight to snowmelt under forest canopy



HOW WILL WE USE DATA FROM THESE SITES?

1) Integrate new measurements onto HFF data dashboard

- Use measurements to help inform operational forecasts

2) Use data to validate, incorporate, and compare to physically-based snow modeling effort

PHYSICALLY-BASED SNOW MODELING

WHAT IS IT?

- Gridded computer models that "build" and melt a snowpack over the water year
  - Model uses the physics of snow accumulation and melt
  - Provides an estimate of snow distribution within a given basin

- Different that traditional water supply models
  - Less dependent on long-term calibrated records
  - More complex, require more resources

- **iSnobal** identified by USBR as a promising, publicly-available modern snow model
  - Initially developed by USDA ARS Northwest Watershed Research Center

Spatially distributed SWE

PHYSICALLY-BASED SNOW MODELING

HOW IT WORKS

Total snowmelt energy

Terms that control snowmelt

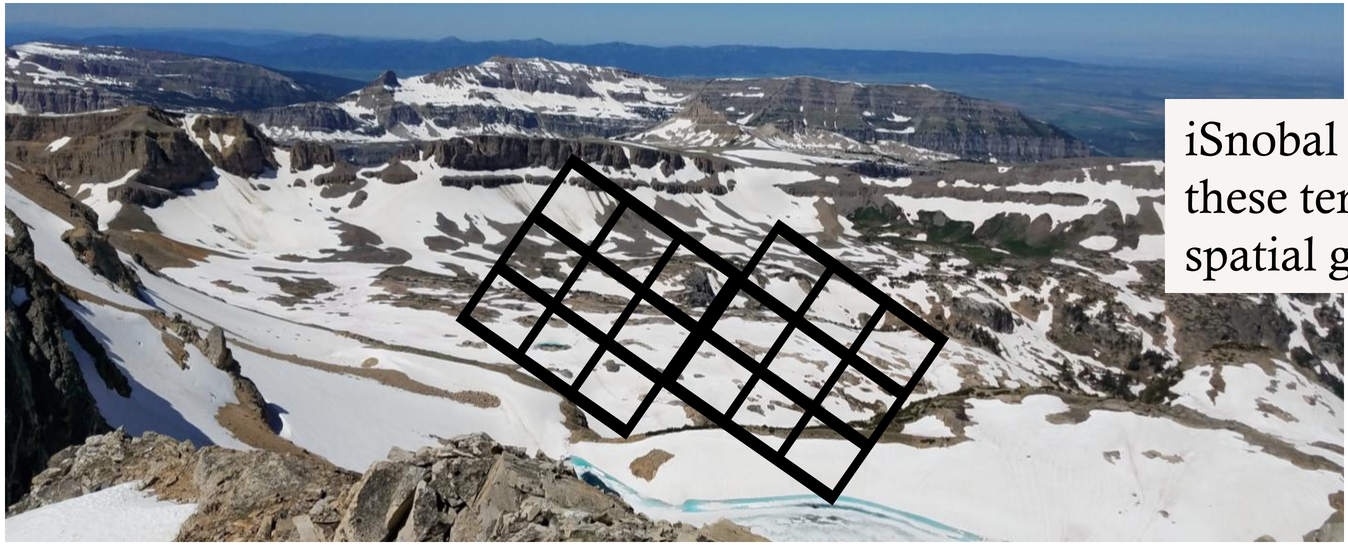
$$ME_{total} = SW_{net} + LW_{net} + S_{net} + L_{net} + Other_{net}$$

Net Solar Radiation · *Net Longwave Radiation* · *Sensible Heat Exchange* · *Latent Heat Transfer* · *Heat from ground, rain, etc.*

Snowpack

melting $ME_{total} > 0$

cooling $ME_{total} < 0$



iSnobal calculates these terms over a spatial grid

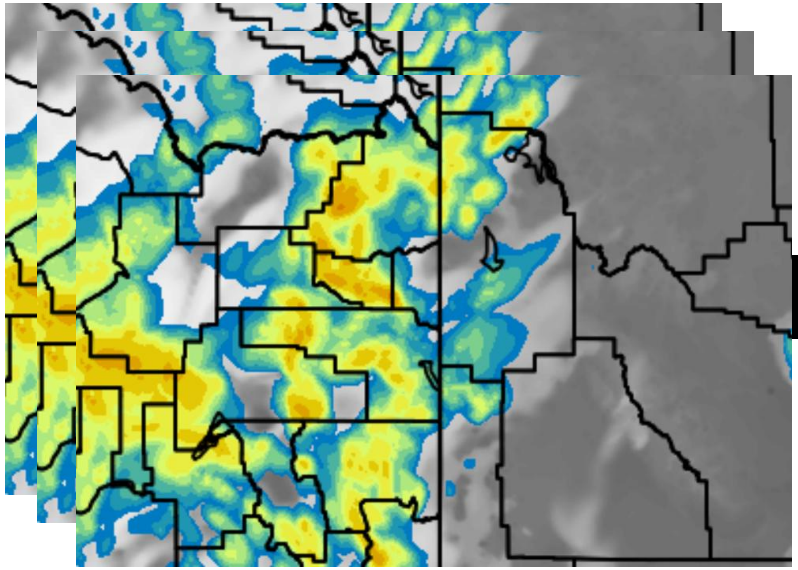
DeWalle & Rango (2008); Marks et al. (1999)

PHYSICALLY-BASED SNOW MODELING

HOW IT WORKS

Hourly inputs from **weather prediction model** – HRRR

- *Precip, temp, radiation, wind, etc.*



High Resolution Rapid Refresh (HRRR)
Benjamin et al. (2016)

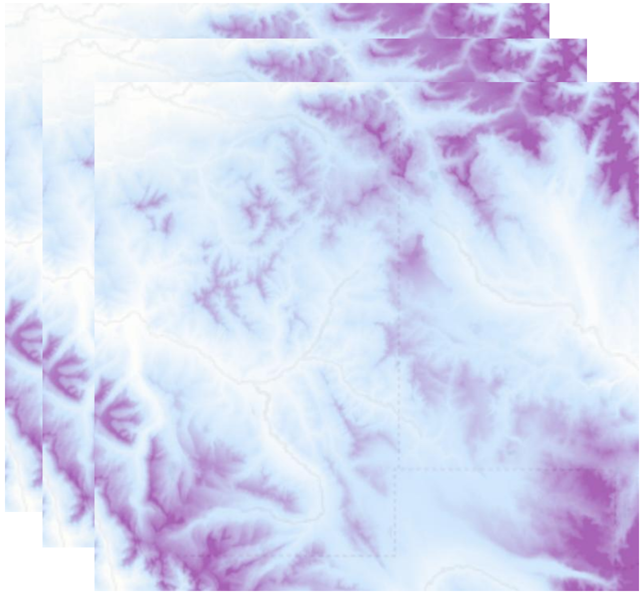
iSnobal

Process-based
Snow mass and energy
balance model

Marks et al. (1999); Meyer et al. (2023)

Daily outputs of Snow parameters

- *Snow depth, SWE, snowpack temp, liquid water content, etc.*



SNOW MODELING: GETTING STARTED

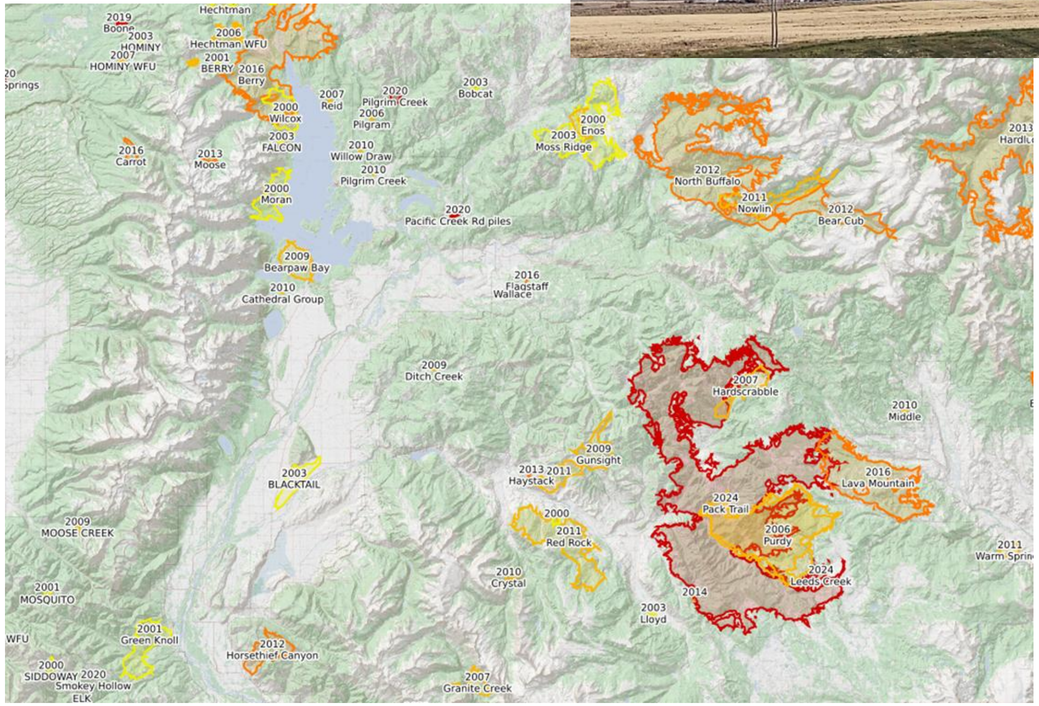
- Snow dominated regions are predominately under forest canopy
  - About 44% of land in headwater regions of the upper Snake is obscured by forest canopy
- **Forests have a large influence on snowpack**
  - Alters how much sunlight reaches snowpack
  - Trees emit thermal radiation that can warm snow
  - Canopy intercepts snowfall
  - Forests reduce wind speed
- **The forest is dynamic**
  - Fire/beetle kill/logging
  - **Need to incorporate changes into modeling** to remain relevant

SNOW MODELING: GETTING STARTED

Model Spin-up: Pack Trail / Fish Creek fire burn scar (August – November 2024)

- Opportunity to **test model performance** under a variety of forest canopy conditions
- **Calibrate model** to be applied elsewhere

e.g., Surunis & Gleason (2024)



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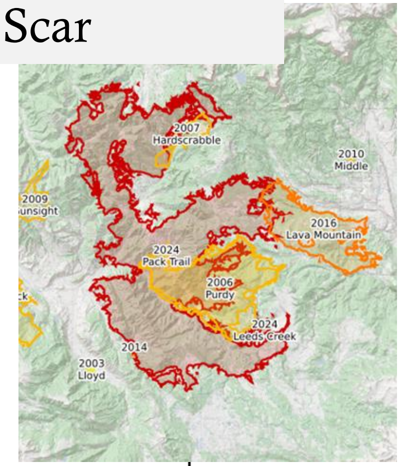
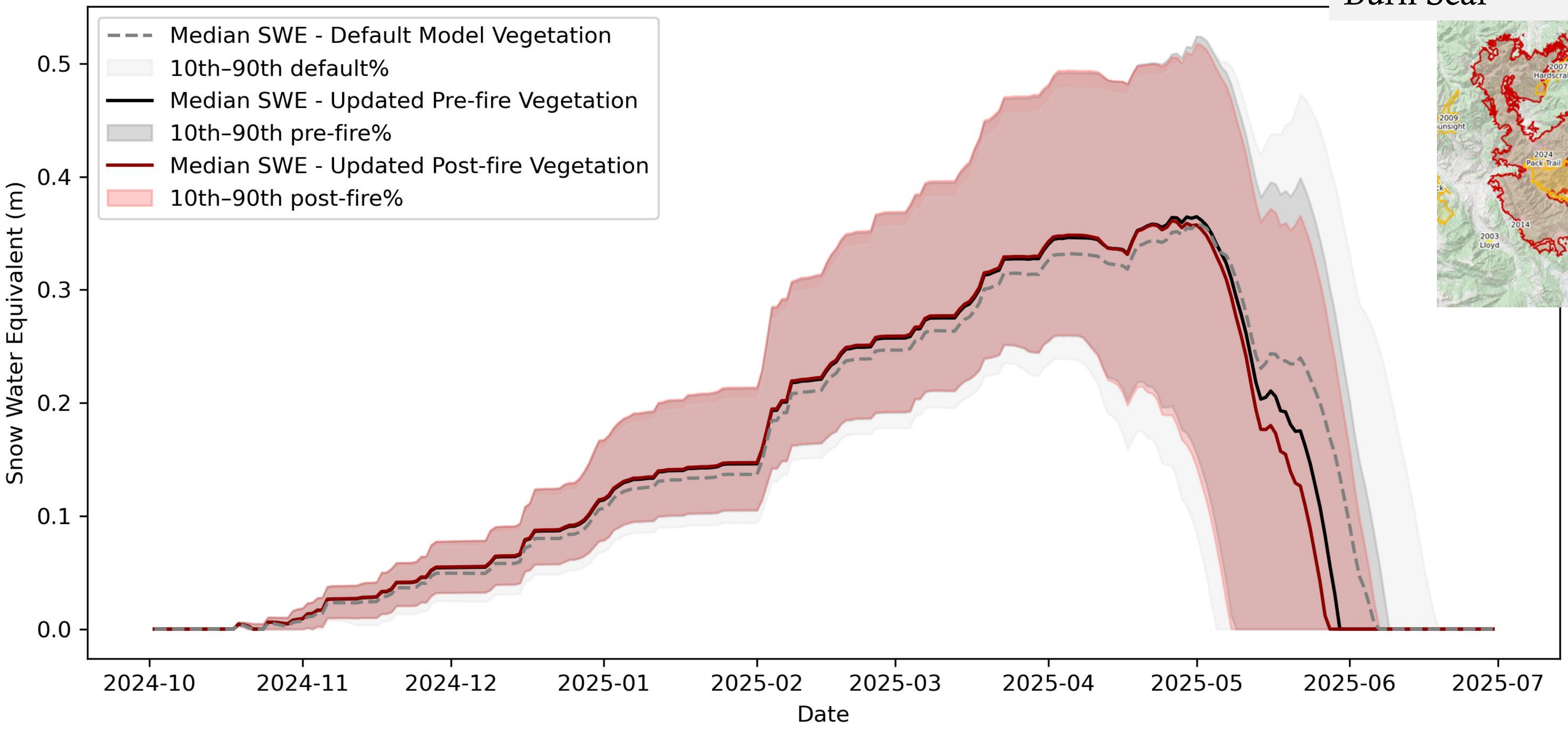
SNOW MODELING: INCORPORATING CANOPY CHANGE

- **Adapting model to incorporate forest change**
  - Leaf Area Index (LAI) measured by Sentinel 2 satellite sensor, Brighter = more canopy area

SNOW MODELING: PRELIMINARY RESULTS

Model Domain:
Burn Scar

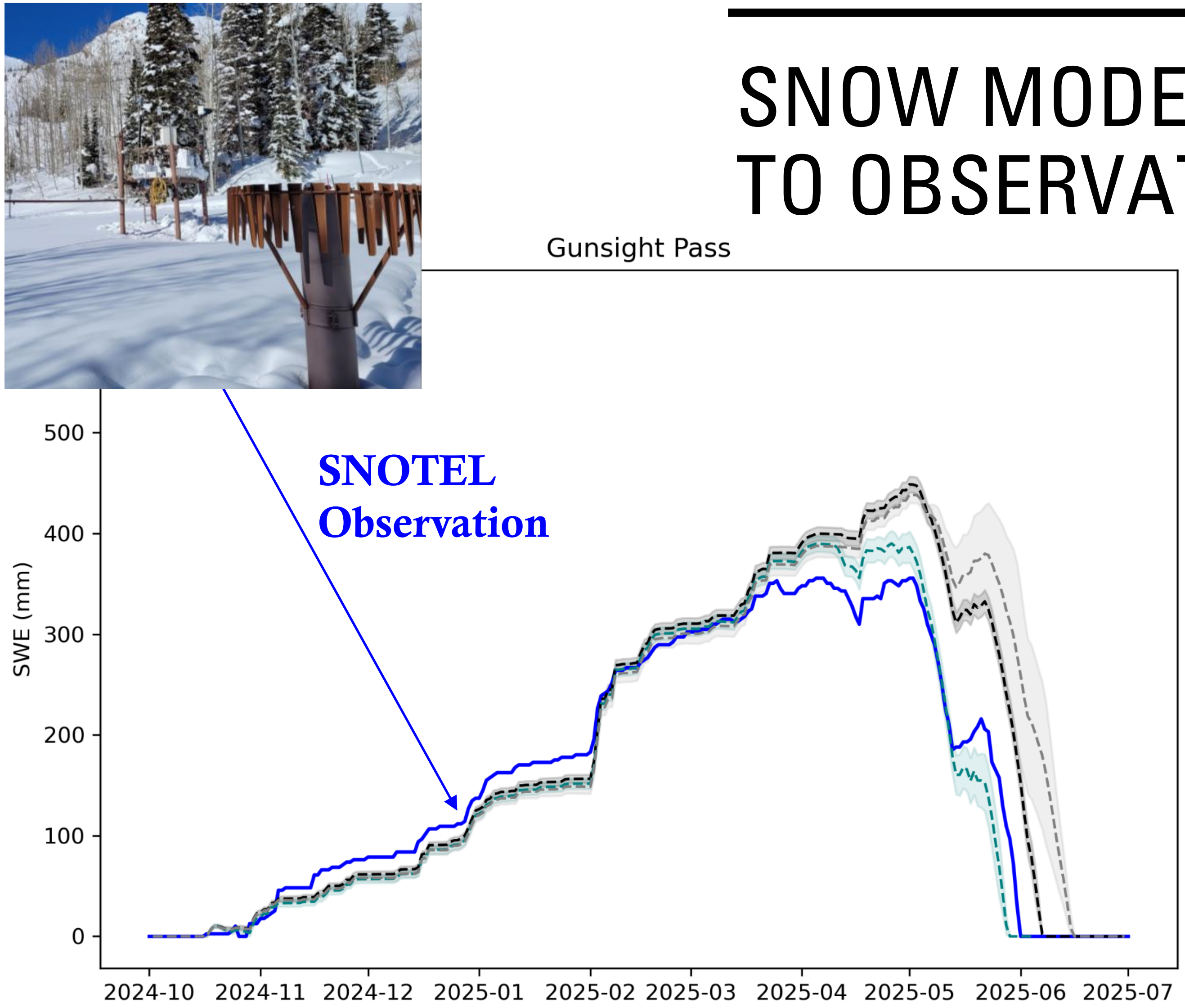




With Burned Vegetation **With Unburned Vegetation** **With Default Vegetation**

Updating the model to include more location-specific vegetation results in a greater change in snowmelt than the impact caused by wildfire

SNOW MODELING: COMPARISON TO OBSERVATIONS



Modeled with optimized vegetation

Modeled with some vegetation updates

Modeled with default vegetation

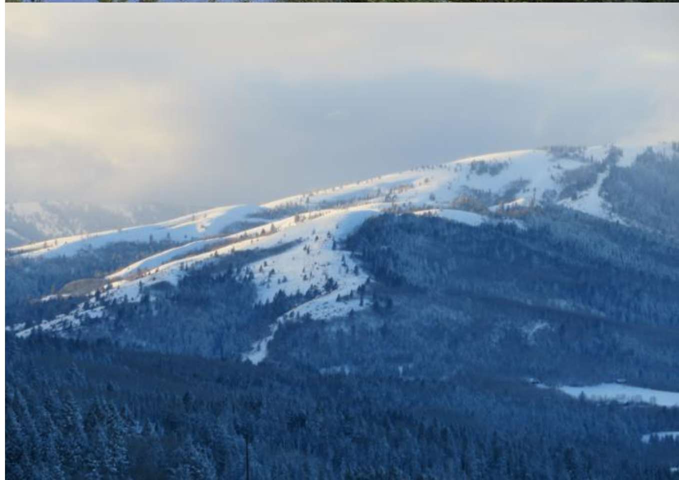
- **Optimize model parameters** & workflow to the vegetation conditions of the upper Snake
- **Make model transferrable** to other regions of watershed
- **Validate outputs** with new station data
- **Apply in near real-time** to assess operational use

SUMMARY

This project will aim to:

1) **Expand hydrologic monitoring** and streamflow prediction across the upper Snake River basin
2) **Install 6 new weather stations** to support operational practices and assist in new modeling efforts
3) **Implement new physically-based snowmelt models** to better predict natural unregulated water supply

Main goal: Continue to improve management of spring-summer reservoir operations with science-driven decision making



THANKS FOR LISTENING!
QUESTIONS?

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REFERENCES

Marks, D., Domingo, J., Susong, D., Link, T., & Garen, D. (1999). A spatially distributed energy balance snowmelt model for application in mountain basins. *Hydrological processes*, *13*(12-13), 1935-1959.

Meyer, J., Horel, J., Kormos, P., Hedrick, A., Trujillo, E., & Skiles, S. M. (2023). Operational water forecast ability of the HRRR-iSnobal combination: an evaluation to adapt into production environments. *Geoscientific Model Development*, *16*(1), 233-250.

Hale, K. E., Jennings, K. S., Musselman, K. N., Livneh, B., & Molotch, N. P. (2023). Recent decreases in snow water storage in western North America. *Communications Earth & Environment*, *4*(1), 170.

Li, D., Wrzesien, M. L., Durand, M., Adam, J., & Lettenmaier, D. P. (2017). How much runoff originates as snow in the western United States, and how will that change in the future?. *Geophysical Research Letters*, *44*(12), 6163-6172.

DeWalle, D. R., & Rango, A. (2008). *Principles of snow hydrology*. Cambridge University Press.

Benjamin, S. G., Weygandt, S. S., Brown, J. M., Hu, M., Alexander, C. R., Smirnova, T. G., ... & Manikin, G. S. (2016). A North American hourly assimilation and model forecast cycle: The Rapid Refresh. *Monthly Weather Review*, *144*(4), 1669-1694.

Van Kirk, R. (2020) Analysis of Water Balance in the Henry's Fork Watershed. Henrys Fork FOundation.

Newcomb, S. K., Van Kirk, R. W., Godsey, S. E., & Kraft, M. (2024). Alignment between water inputs and vegetation green-up reduces next year’s runoff efficiency. *Hydrological Processes*, *38*(6), e15211.

Surunis, A., & Gleason, K. E. (2024). Modelling postfire recovery of snow albedo and forest structure to understand drivers of decades of reduced snow water storage and advanced snowmelt timing. *Hydrological Processes*, *38*(7), e15246.